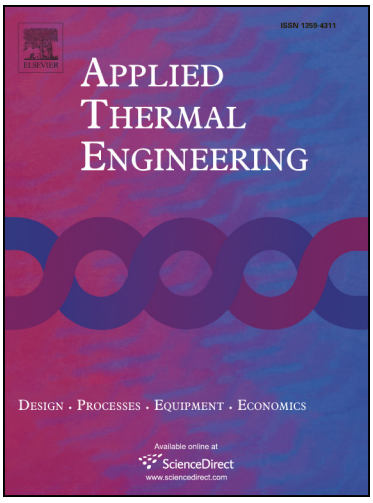

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The Heat Transfer Characteristic of Shell-side Film Flow in Spiral Wound Heat Exchanger under Rolling Working Conditions

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Abstract: In order to explore the shell-side heat transfer characteristic for spiral wound heat exchanger (SWHE) in floating liquefied natural gas (FLNG) field, a model was established to simulate the heat transfer of shell-side film flow in real working conditions. The influence of rolling parameters and working parameters on shell-side heat transfer characteristic was investigated. For ethane, the results showed that the numerical model satisfies the accuracy requirement. In general, under static working conditions, the heat transfer coefficient increases with the increase of mass flux and the decrease of working pressure, but heat flux has little influence on it. These simulation results were consistent with experimental data and calculation results by correlations. And the heat transfer coefficient shows obvious periodicity under rolling working conditions. The rolling movement can enhance the heat transfer of shell-side film flow, and the influence of different parameters on heat transfer is different. These results will provide some instructions in the design and safe operation for SWHE in FLNG.

Keywords: spiral wound heat exchanger (SWHE); film flow; heat transfer; rolling working condition; numerical simulation

1. Introduction

Spiral wound heat exchanger (SWHE), as a type of compact exchangers, has been gradually used as main cryogenic exchanger in liquefied natural gas (LNG) plants. The use of SWHE in LNG plants is due to its advantages of high reliability, high compactness, high flexibility (for temperature and pressure), better robustness (in the process of opening/closing and sailing), small temperature difference, efficient heat transfer, and so on [1-3]. These advantages have led to SWHE widely applied in large-scale onshore LNG plants. However, the most important point is SWHE has an enormous potential in large-scale floating liquefied natural gas (FLNG) plants.

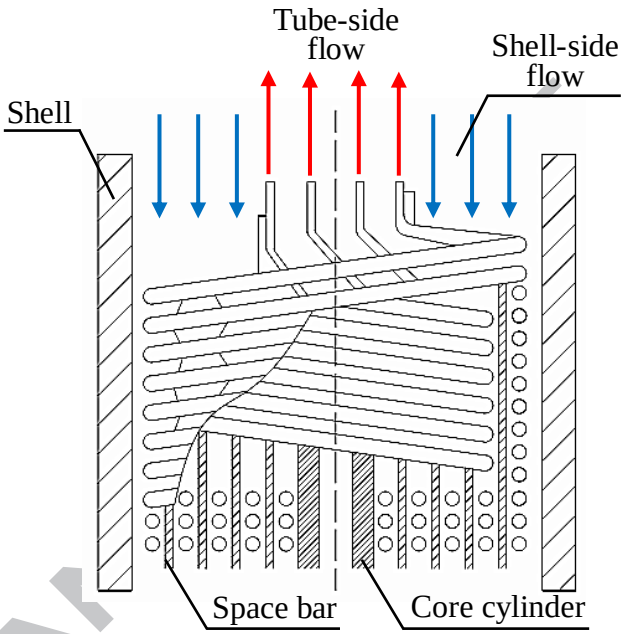

Fig. 1 A sketch map of complex flow in SWHE

Fig. 1 shows a sketch map of complex flow in SWHE. It contains two important flows: tube-side flow and shell-side flow. The process of liquefying natural gas in the SWHE is implemented through the heat transfer between natural gas flowing upward in tube side and refrigerant flowing downward in shell side. As is shown, the shell-side flow of hydrocarbon refrigerant is more complicated than tube-side flow. The shell-side heat transfer characteristic actually has more significant influence on the performance of SWHE [4]. However, the directly related reference about SWHE shell side is pretty scant. Considering the fact that the shell side of horizontal tube bundle or helically coiled tube heat exchanger can be treated as the simplification and deformation of SWHE shell side, many references are valuable and should be introduced for helping the research on heat transfer characteristic in SWHE shell side.

In earlier experimental studies from Fredheim [5] and Aunan [6], the description of different heat transfer mechanisms was based on fluid hydrodynamics, and SWHE shell side may be divided into four different zones according to main driving force for fluid flow: (1) film flow; (2) transient flow; (3) shear flow; (4) superheated flow (belongs to single-phase flow). Coates et al. [7] firstly gave the heat transfer correlation for shell-side flow, which was applicable to single-phase flow. According to the research results, the shell-side heat transfer coefficient increased

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